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AVCAL'S EFFECTIVENESS IN SUPPORTING OPERATIONS WITHOUT RESUPPLY OF AVIATION SPARE PARTS

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MEMORANDUM FOR ASSISTANT CHIEF OF NAVAL OPERATIONS (AIR WARFARE) (OP-05)
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1. Enclosure (1) is forwarded as matter of possible interest.

2. This research memorandum examines the capability of a deployed aircraft carrier's AVCAL to meet the goal of supporting wartime operations for 90 days without resupply.

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BACKGROUND

To reduce losses in operational capability caused by predicted delays in obtaining logistics support, defense guidance goals call for military units capable of sustaining wartime operations for long periods of time without outside support. As part of the Navy's attempt to meet these goals for carrier-based air wings, the carrier is self-sufficient in terms of aircraft maintenance and spare-part support. In particular, the stockpile of aviation spare parts carried on board a carrier is intended to provide sufficient spares for 90 days of wartime operations with no off-ship resupply of aviation parts. This stockpile of aviation spare parts is called the Aviation Consolidated Allowance List (AVCAL).

The AVCAL's size and composition is based on historical data describing the failure and repair characteristics of the air wing and represents an educated projection of wartime spare-part needs. However, the future maintenance needs of the air wing cannot be predicted with certainty, and the AVCAL will undoubtedly be deficient in some areas because unforeseen changes in maintenance needs will occur. In addition, the AVCAL represents spare-part requirements; the actual levels of spare parts deployed on the carrier may be below authorized AVCAL stock levels because of shortages in the Navy supply system.

As part of the Carrier Air-wing Self-Sufficiency study, CNA analysts investigated the capability of a deployed carrier's AVCAL to meet the goal of supporting wartime operations for 90 days without resupply. The study team focused on two main issues: (1) whether the AVCAL can support operations for 90 days, and, if not, the extent of the problem, and (2) the role of "pieceparts," i.e., items used to repair higher-level aircraft parts, in sustaining aircraft operations.

After careful consideration of the data available to study this issue, the study team selected the following approach. First, a technique was developed to reconstruct histories of aircraft carrier deployments from maintenance action forms (MAFs) and flight records.[1] The technique allows the reconstruction of on-hand stock levels at the beginning of the deployment. Finally, wartime performance is projected by accelerating the peacetime deployment history to a

1. MAFs (form OPNAV 4790/60) are the source document for all Navy aviation maintenance data. MAFs are also called Visual Information Display System, Maintenance Action Forms (VIDS/MAF). Flight records (form OPNAV 3710/4) are the source document for the Navy aircraft flight data.

wartime operating tempo and measuring the effectiveness of the reconstructed on-hand stock levels in meeting demands without off-ship resupply of aviation spare parts.

The results contained in this paper are based on an analysis of the 1987 deployment of USS *Constellation*. At some later date, the analysis may be continued with additional data sets, but significant changes in these results are not anticipated.

The study team concluded that a carrier's AVCAL will not support wartime operations for 90 days without resupply. However, the AVCAL does perform well in reducing the need for off-ship support: the shortfall in AVCAL effectiveness is small in the sense that about one carrier on-board delivery (COD) sortie per day will be enough to provide both the required level of off-ship resupply of aviation spare parts and typical (peacetime) levels of non-aviation high-priority cargo. The study team also concluded that improving piecepart levels in the AVCAL can significantly reduce the need for off-ship resupply of higher-level aircraft parts; however, no amount of piecepart support will eliminate the need for off-ship resupply support, including about one COD sortie per day. (Regardless of the level of piecepart support, many aircraft parts are not repairable; these types of parts make up a significant portion of the AVCAL effectiveness shortfall.)

The analysis does not indicate the need for a drastic change in AVCAL policy. The number of "bad" part numbers is small in comparison to the total range of parts carried in the AVCAL; that is, the AVCAL sufficiently covers demands for almost all part numbers. Navy-wide shortages probably contribute to some of the AVCAL problems; however, most of the problems can be attributed to chance. Given the large range of part numbers, the probability of accurately forecasting demand for all parts needed by the air wing is small. Indeed, the AVCAL development process uses data from previous deployments to adjust allowance levels; it is likely that many of the "bad" part numbers in a particular deployment experienced few stockouts in previous deployments. Although slight improvements in AVCAL support may be possible, attempting to totally eliminate the need for off-ship support is not a reasonable goal.

This paper is organized as follows. The remainder of this section discusses the decision to adopt the "reconstructed AVCAL" approach used in this analysis. The next section summarizes the methodology and presents the results of the analysis. The final section contains technical details of the study methodology.

REASON FOR SELECTING THE RECONSTRUCTED AVCAL APPROACH

Originally, the study team planned to obtain AVCAL-related data, including national item identification number (NIIN), spare-part allowance levels, and a tailored manufacturer's part-number-to-NIIN cross-reference, from the Aviation Supply Office (ASO) for several recent aircraft-carrier deployments. A deployed carrier's AVCAL thus obtained from the ASO would be evaluated in a simulation of wartime operations based on MAF and flight record data from the deployment.

The study team found that these AVCAL-related data were not archived by the ASO and, hence, were not available for use in the study. Rather than task each carrier to provide the information, at considerable inconvenience to the carrier's supply department, alternative arrangements were made with the ASO. Shortly after each carrier deployment, the carrier and the ASO compute AVCAL requirements for the next deployment of the carrier; at a certain point in this AVCAL development process, all of the data thought needed for the study are available. The ASO agreed to "capture" the data at the appropriate time and make them available to CNA.

The arrangement with the ASO has succeeded, and CNA is starting to receive and archive these data for future use. The first set of AVCAL-related data from the ASO was for the 1987 deployment of USS *Constellation.* As this data set was processed in preparation for use in the analysis, a number of problems regarding data quality were found. These problems are discussed below.

An important data processing step must be successfully completed before the authorized AVCAL stock levels from the ASO can be evaluated as originally planned against the historical maintenance data from the carrier's deployment. Supply personnel use NIIN to identify parts, and maintenance personnel use manufacturer's part number; in particular, authorized AVCAL stock levels are listed by NIIN in the ASO AVCAL data; historical demand and repair data are documented in MAFs by part number. Hence, the listing of stock levels by NIIN in the ASO data files must be converted to a listing by manufacturer's part number. This conversion process is complicated by numerous factors, including interchangeability considerations, alternative NIINs, and alternative or conflicting part number assignments; however, a tailored part-number-to-NIIN reference was included among the AVCAL-related data received from the ASO.

As shown in more detail in table 1, only 70 percent of the ASO AVCAL list was identified with a manufacturer's part number through the tailored part-number-to-NIIN cross-reference provided by the ASO. Informal discussions with ASO personnel indicate that these are typical results.

Table 1. 1987 *Constellation* ASO AVCAL data: part-number-to-NIIN matches

Total number of AVCAL NIINs	Percent matched with PN	Percent not matched with PN
74,347	64	36
Total number of units carried in AVCAL (AVCAL depth)	**Percent matched with PN**	**Percent not matched with PN**
1,077,131	76	24
Total number of AVCAL NIINs with AVCAL level greater than 5	**Percent matched with PN**	**Percent not matched with PN**
13,198	71	29

Given a list of authorized AVCAL stock levels by manufacturer's part number, the AVCAL can be evaluated against historical maintenance data only by matching the AVCAL levels against failure and repair data documented in MAFs. A list of part numbers recorded on MAFs from the 1987 USS *Constellation* deployment was developed to compare against the AVCAL levels from the ASO. The MAF data are extremely "dirty" and contain many instances of part-number spelling errors. In addition, part numbers for about 30 percent of the ASO AVCAL list were not known, and some low-failure-rate items are never assigned NIINs by the government supply apparatus. As a result, only 20 percent of the MAF part numbers matched with an ASO AVCAL part number. No attempt was made to correct spelling errors in this comparison; however, the poor result indicates the severity of the data-quality problem.

Without significant additional efforts to develop alternative data sources and to clean up the 1987 USS *Constellation* data set, only 70 percent of the ASO AVCAL can be identified with a part number, and only 20 percent of the part numbers documented on MAFs can be matched with an allowance level. This level of data quality was clearly unacceptable for the purposes of this study; moreover, the poor initial data quality would make the quality of a "scrubbed" data set suspect. Based on past experience at CNA, efforts at improving the data quality would be time consuming, must be repeated separately for each carrier studied, and would have a low probability of success. For these reasons, the study team decided to abandon the original approach of using the ASO AVCAL data.

The alternative "reconstructed AVCAL" approach was selected primarily because it is based on a single data set (historical MAFs), eliminating the problems experienced in matching the ASO AVCAL data and the historical MAF data. In retrospect, the alternative procedure of reconstructing AVCAL levels from the historical data is preferable because the reconstructed AVCAL levels correspond to the carrier's on-hand stock levels at the beginning of the deployment rather than the "authorized stock level" documented in the ASO data. Also, the reconstructed AVCAL method reduces the analytical problems caused by part-number spelling errors in the maintenance data.

SUMMARY OF METHODS AND RESULTS

This section summarizes the study methodology and discusses the results of the analysis. The procedure used to reconstruct AVCAL levels is summarized, and an example is given. Reconstructed AVCAL levels are compared to the ASO's authorized AVCAL stock levels where a match between part numbers was found. Next, the procedure used to evaluate the reconstructed AVCAL is summarized, and an example is given. Finally, the results of the analysis are presented.

RECONSTRUCTED AVCAL LEVELS

The basic idea behind reconstructed AVCAL levels is simple: the reconstructed AVCAL level is the lowest stock level that is consistent with the historical record of the carrier's deployment as documented on MAFs, given an assumed off-ship supply response time during the deployment. As explained below, the reconstructed AVCAL level is based on two pieces of information developed from historical data: a time line of supply-room transactions and a fill rate.

MAFs contain several data elements, recorded by part number, that may be used to reconstruct supply-room transactions:

- The time of each demand on the supply room for a replacement part, at which time a replacement part will be issued from supply if a spare is available.
- For parts repairable in the carrier's Aircraft Intermediate Maintenance Department (AIMD), the results of AIMD work is recorded: either (1) the time of a successful completion of repair of the part, at which time the repaired part is returned to the supply room, or (2) the time of a beyond the capability of maintenance (BCM) declaration, at which time an off-ship requisition for a replacement part is generated. (This analysis assumes that a demand for a consumable part, that is, a part not repaired on ship, will automatically result in an off-ship requisition for a replacement part.)

If, in addition to the historical data elements above, the time required to fill each off-ship requisition was known, it is theoretically possible to reconstruct exactly the historical sequence of supply-room transactions. Unfortunately, the off-ship response time is not available in MAF data, and it is necessary to make some assumptions about off-ship supply response time in order to develop a

reconstructed record of supply-room transactions. For most of the applications in this paper, a fixed 45-day off-ship resupply time is assumed.

MAFs also contain data that make it possible to reconstruct the historical fill rate: the awaiting-parts (AWP) delay between the request for a spare part by maintenance personnel and its receipt from supply. Fill rate is defined by $\frac{d-s}{d}$, where d is the number of demands for spare parts, and s is the number of demands that were not filled immediately. In other words, the fill rate is the probability that replacement parts are in stock at the time first requested. In this analysis, an AWP time greater than three days was assumed to correspond to a stockout; shorter AWP times were assumed to correspond to an in-stock condition. This procedure leads to fill rates that are biased slightly high; in turn, this tends to produce reconstructed AVCAL levels that are biased slightly high.

Two pieces of information are thus developed for each part number: (1) a time line of supply-room transactions based on historical demand and repair data and an assumed off-ship resupply time, and (2) an historical fill rate based on historical demands and AWP times. These two pieces of information were combined in the computation of a reconstructed AVCAL level. Given a hypothetical initial stock level, the time line of historical supply-room transactions may be simulated, allowing the calculation of a simulated fill rate. The reconstructed AVCAL level is defined to be the smallest initial stock level that produces a simulated fill rate as high as the historical fill rate.

Figure 1 contains a simple example. Shown at the top of the figure is the historical time line of demands for a part number along with the historical fill rate of $\frac{16}{20}$. For simplicity, this example considers a consumable item: an off-ship order for replacement parts is placed each time a demand is made on the supply room. If a fixed 45-day off-ship resupply time is assumed, the time line of demands and off-ship receipts shown in the middle of the figure will result. If an initial stock level of 10 is assumed, the resulting sequence of supply-room transactions, shown at the bottom of the figure, will produce a fill rate of $\frac{16}{20}$. It follows that the example part's reconstructed AVCAL level for a 45-day resupply time is 10 units.

It is important to note that reconstructed AVCAL levels represent minimum stock levels consistent with the historical record. If the historical fill rate associated with a part number is 100 percent, the reconstructed AVCAL level is just sufficient to ensure that the 100-percent historical fill rate is reproduced; however, the true stock level carried on board the carrier could have been higher than the reconstructed AVCAL level. If the historical fill rate is less than 100 percent,

Historical fill rate: $\frac{16}{20}$

Historical time line of demands:

Number of demands

8 (day 0) ⇓   4 (day 30) ⇓   8 (day 50) ⇓

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 (Day)

Simulated time line with 45-day off-ship resupply:

Number of demands

8 (day 0) ⇓   4 (day 30) ⇓   8 (day 50) ⇓

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 (Day)

⇑ 8 (day 45)   ⇑ 4 (day 75)   ⇑ 8 (day 95)

Number of receipts from off-ship

Simulated supply-room transactions with 45-day off-ship resupply and initial stock level 10:

Day	Stock level	Back orders	Cumulative stockouts
-1	10	0	0
0	2	0	0
30	0	2	2
45	6	0	2
50	0	2	4
75	2	0	4
95	10	0	4

Simulated fill rate: $\frac{16}{20}$

Reconstructed AVCAL level: 10

Figure 1. Example of reconstructing AVCAL levels

that is, if there were stockouts during the deployment, the reconstructed AVCAL level should be a reasonably accurate estimate of the true stock level.

Using the procedure summarized above, reconstructed AVCAL levels were calculated for three different off-ship resupply times: 15 days, 45 days, and 90 days. As off-ship resupply times increase, the reconstructed AVCAL levels will tend to increase; however, as indicated in table 2, reconstructed AVCAL levels are not overly sensitive to the off-ship resupply time parameter.

Table 2. Sensitivity of reconstructed AVCAL levels to off-ship resupply time

N	Percent of part numbers where the difference between the 15-day and 90-day levels is not greater than N
0	86
2	96
10	99
	(Total number of distinct part numbers is 19,195)

As mentioned earlier, the ASO AVCAL levels were matched to about 20 percent of the part numbers recorded in the MAF data. Reconstructed AVCAL levels were computed for each of the MAF part numbers. (A 45-day resupply time was used in the calculation.) A comparison between the two stock levels for matching part numbers is summarized in table 3. The left set of figures compares levels for all cases in which a match was found, and the right set of figures compares only matching cases for which the historical fill rate was less than 100 percent. In both cases, the ASO level tends to be higher than the reconstructed AVCAL level; this is to be expected because the reconstructed AVCAL level represents an on-hand level and would normally be below the ASO's authorized AVCAL stock level. The reconstructed AVCAL level should be a more accurate estimate of actual stock levels if the historical fill rate was less than 100 percent; this is supported by the the second set of figures. In general, on-hand levels and the ASO's authorized AVCAL levels cannot be expected to match exactly. The relatively close agreement between the ASO AVCAL levels and reconstructed AVCAL levels displayed in table 3 convinced the study team that the technique

used to compute reconstructed AVCAL levels produces results that are accurate enough to assess AVCAL effectiveness at the level-of-detail addressed in this study.

Table 3. Comparison of reconstructed AVCAL level to ASO AVCAL level

	Percent of part numbers with ASO AVCAL level less 45-day reconstructed AVCAL level in the indicated range	
Range	ASO matches[a]	ASO matches with peacetime stockouts[b]
$<$ -3	4	1
-3 to -1	14	18
0	27	33
1 to 3	29	34
$>$ 3	25	14

a. Out of a total of 19,195 part numbers listed in MAF data, 4,124 could be matched with ASO AVCAL data.

b. The number of matching part numbers that experienced peacetime stockouts is 803.

COUNTING BACKORDERS

To evaluate the effectiveness of the reconstructed AVCAL, a procedure was developed to estimate the number of backorders that would occur during a period of wartime flight operations with no off-ship resupply of aviation spare parts. The basic idea is: (1) the historical (peacetime) failure and repair characteristics of each part are assumed to hold in wartime, (2) the number of failures that would be expected over a period of wartime operations is calculated, and (3) the effects on the repair of higher-level parts caused by stockouts of lower-level subparts is

calculated. The final result is an estimate of the number of backordered aircraft-removed parts at the end of the period of wartime operations.[1] From the number of backorders, it is possible to calculate the number of aircraft-level maintenance actions that will be halted in AWP status. In effect, the technique addresses the following question: How many stockouts will be experienced and how will the stockouts affect aircraft?

The method used to compute the number of backorders is best summarized through an example, provided in figure 2. First, the MAF data from the deployment are used to recover aircraft indenture structure and certain maintenance and repair statistics. (Aircraft indenture structure is the breakdown of the part-to-subpart relationships among the different parts that make up an aircraft.) A simple one-aircraft, three-part example is shown in figure 2. In actuality, each aircraft type has thousands of subparts and many different indenture layers. (The MAF data record up to four indenture levels.) In addition, a given part number may be used in several different applications. Also computed from MAF data are maintenance factors such as failure rates, repair rates, and a complicated measure of the repair-demand relationship between parts and their subparts. The maintenance factors for the example are shown in figure 2.

The initial stock levels shown in the example in figure 2 are evaluated over a period of 1,000 sorties of aircraft type A. The individual steps used to compute the effect of lower-level parts are shown near the middle of figure 2. In step 1, the number of removals for part 1 is computed first, then the number of demands for the lower-level parts 2 and 3. At step 2, the number of backorders for the lowest-indenture parts is computed; based on the initial stock levels, there are one and four backorders for parts 2 and 3, respectively. At step 3, the effect of the lower-indenture level backorders on part 1 is computed. Note that the historical data indicate that part 3 is ordered in pairs; hence, the four backorders for part 3 affect only two repairs of part 1. At step 4, the total number of repairs of

1. Aircraft-removed parts are defined as parts removed directly from the aircraft. AIMD-removed parts are defined as a part not removed directly from the aircraft, but removed at the AIMD from a higher-level aircraft part. These categories are divided into two additional categories: consumable (parts that are not repaired on ship), and repairable (parts that are repaired on ship). Note that consumable items removed directly from the aircraft are considered aircraft-removed parts in this analysis, regardless of how inexpensive they may be. This terminology is introduced to eliminate possible misunderstandings. Among Navy maintenance and supply personnel, weapon replaceable assembly (WRA) is often used to refer to repairable items removed from the aircraft, and shop repairable/replaceable assembly (SRA) is used for repairable items removed at the AIMD. The term piecepart is often used for inexpensive consumable items. Unfortunately, the terms WRA, SRA, and piecepart are not well defined. For example, some people consider expensive, aircraft-removed consumable parts to be WRAs; other people use WRA for only repairable items.

Indenture structure:

	A	Aircraft
	↓	
	1	Level 1 (Aircraft-removed part)
↙	↓	
2	3	Level 2 (AIMD-removed parts)

Maintenance factors:

Part 1:	0.01	Removals per aircraft A sortie
	1	Item requested given a maintenance action on aircraft A needing part 1
	0.90	Repair rate given all parts available
Part 2:	0.10	Removals per induction of part 1
	1	Item requested given a repair of part 1 needing part 2
Part 3:	0.60	Removals per induction of part 1
	2	Items requested given a repair of part 1 needing part 3

Inputs:

1,000	Number of sorties of aircraft A
2	Initial stock level of part 1
0	Initial stock level of part 2
2	Initial stock level of part 3

Calculation of the effect of lower-level parts:

		Part 1	Part 2	Part 3
Step 1	Number of demands	10	1	6
Step 2	Number of backorders for lowest-level parts	–	1	4
Step 3	Number of higher-level repairs halted due to AWP	–	1	2
Step 4	Number of high-level parts in AWP status	2	–	–

Backorder calculations for part 1:

Number of demands: 10
Number of parts stocked: 2
Number of repairs possible given all parts available: 9
Number of repairs halted due to AWP condition: 2
Number of backorders (demands less number in stock and repaired): $10 - 2 - (9 - 2) = 1$
Number of maintenance actions of aircraft A halted in AWP status: 1

Figure 2. Counting backorders—example 1

part 1 that must be halted because of an AWP condition is computed, assuming full cannibalization is allowed. Next, the number of backorders for part 1 is computed: the number of demands less the number stocked or repaired is one. Finally, because each order of part 1 corresponds to only one maintenance action on an aircraft, the number of AWP maintenance actions on aircraft type A is one.

The example illustrates the basic principles used to estimate the number of AWP aircraft-level maintenance actions at the end of a period of wartime operations. The actual calculations used in this analysis are complicated by the fact that actual aircraft indenture structures are much more complex than that of the example. The actual calculations also consider on-ship repair times. Additional details, including a more complicated example, are provided in the section titled "Technical Details."

RESULTS

The methods summarized above were used to evaluate the performance of the reconstructed AVCAL over a period of 90 days of wartime flight operations without off-ship resupply of aviation spare parts. This section discusses the effectiveness of the AVCAL over the 90-day period, then the effectiveness of the AVCAL over 30- and 60-day periods. This is followed by a discussion of the role of subparts in sustaining operations over the 90-day period.

As mentioned earlier, the results are based on MAF data collected during the 1987 deployment of USS *Constellation*. The number of sorties flown over the wartime period was based on a sortie rate of one per day and the air wing composition shown in table 4.

Table 4. Air-wing composition

Aircraft type	Air-wing population
F-14	24
F-18	24
A-6	10
KA-6	4
E-2	4
EA-6	4
S-3	10
SH-3	6

A simple count of the number of backorders is not a good measure of the effectiveness of an AVCAL. Consider a simple example based on a total of ten backordered parts: If all ten of the items have different part numbers, it is possible, with cannibalization, that only one aircraft is down due to missing parts. If all ten backordered items have the same part number, however, it is possible that ten aircraft are down due to missing parts. Because of these considerations, two relatively complicated measures of effectiveness, AWP(N) and P(N), are used to report results. Together, AWP(N) and P(N) provide information on the number of AWP maintenance actions at the aircraft level, the number of part applications associated with backorders, and a rough measure of the effect of backorders on aircraft availability.[1]

The procedures used to record maintenance data on MAFs make a precise, easy-to-understand description of AWP(N) and P(N) impossible; however, the following imprecise description is essentially correct. (Precise definitions are given in the section titled "Technical Details.") If as many AWP maintenance actions as possible are consolidated through cannibalization on N aircraft per type, the number of AWP maintenance actions outstanding on the other aircraft is AWP(N), and the corresponding number of "bad" part applications is P(N). Hence, AWP(N) is the number of outstanding AWP maintenance actions past the point where up to N cannibalized aircraft of each type are "tolerated," and P(N) is the number of aircraft-removed part applications causing more than N AWP maintenance actions. For $N = 0$, AWP(0) is simply the total number of

1. A backorder for two parts may halt only one maintenance action, for example, if a single maintenance action requires two units of a particular part number. If, for example, a particular part number is used on two distinct aircraft types, the part has two applications.

AWP maintenance actions, and P(0) is the total number of aircraft-removed part applications with backorders.

Going back to the earlier example of ten backordered parts, if all ten backordered parts have different part numbers and each is associated with a distinct maintenance action, then AWP(0) = 10 and AWP(1) = 0, indicating it is possible that all AWP maintenance actions may be consolidated on one aircraft of each type. Other situations are more complicated; for example, suppose all ten backordered parts have the same part number, and two aircraft types are involved, say with five backorders attributed to each type. Consider this last example with $N = 1$: AWP(1) = 8 indicates that after "tolerating" up to one cannibalized aircraft of each type, there are still eight outstanding AWP maintenance actions; P(1) = 2 indicates that the eight AWP maintenance actions are associated with two part applications.

Table 5 shows upper and lower bounds of AVCAL effectiveness over a 90-day wartime scenario with no off-ship resupply. The results labeled LO correspond to reconstructed AVCAL levels for all part numbers. A peacetime off-ship resupply time of 45 days was assumed in the calculation of reconstructed AVCAL levels. As discussed earlier, the reconstructed AVCAL level is accurate for items that have historical fill rates less than 100 percent and is a lower bound for the stock level of items that have historical fill rates of 100 percent. To obtain the results labeled HI, the items with a 100-percent historical fill rate were given infinite initial stocks, and the remaining items were given the 45-day reconstructed AVCAL level. Hence, the LO and HI AVCALs represent lower and upper bounds, respectively, on the actual spare-parts package carried during the aircraft carrier's deployment. The table contains AWP(N), P(N), and a rough estimate of the COD sortie rate needed to provide the carrier with the backordered aircraft-removed parts.[1] The values of AWP(N) and P(N) reported in the table were rounded to one significant digit after their calculation.

1. Briefly, COD aircraft have both cargo weight and cube limitations; however, volume is almost always the limiting factor. A review of CNA data indicates that 5 cubic feet is a reasonable estimate for the average size of an aircraft-removed part. The data also indicate that the high-priority cargo other than mission-essential aircraft parts, including ship parts, personnel, and mail, averages 500 cubic feet per day. The usable volume of a of a COD C-2A aircraft is about 700 cubic feet. This leads to the estimate $\frac{5n+500}{700}$ for the COD sortie rate if the number of aircraft parts transported per day is n. AWP(N) is used to approximate the number of parts n in the COD sortie rates reported in table 5.

Table 5. Backorder calculations for 90 days of wartime operations without resupply

	LO[a]			HI[b]		
N	AWP(N)	P(N)	COD rate	AWP(N)	P(N)	COD rate
0	2,000	800	0.9	500	200	0.8
1	1,000	300	0.8	300	80	0.7
2	700	200	0.8	200	50	0.7
3	600	100	0.8	100	40	0.7
4	400	–	0.7	90	–	0.7

a. LO: Reconstructed AVCAL with 45-day resupply time.
b. HI: Same as LO AVCAL except items with historical fill rate of 100 percent given infinite stock level.

As shown in table 5, the AVCAL will not support wartime flight operations for 90 days without off-ship support; between 500 and 2,000 AWP maintenance actions at the aircraft level will exist at the end of the 90-day period. Of particular interest are the results for the HI AVCAL; these results project the wartime implications of actual peacetime supply problems because items that did not experience peacetime problems during the historical deployment are given infinite stock levels. The fact that AWP(3) = 100 indicates that there are about 100 AWP aircraft-level maintenance actions past the point where up to three cannibalized aircraft of each type are tolerated; as P(3) = 40, this shortfall is due to problems in about 40 part numbers. A willingness to accept high numbers of cannibalized aircraft will not eliminate the need for off-ship support.

It is important to note that the results in table 5 indicate the extent of the problem is small when the total number of "bad" part numbers is compared to the total range of parts carried in the AVCAL; most part numbers will not experience backorders. However, a small minority of part numbers will experience high numbers of backorders, causing several aircraft to be down.

Table 6 presents results for 30 and 60 days of wartime operations with no resupply. Together with table 5, this provides an indication of how rapidly backorders grow. More importantly, the results indicate that it is unrealistic to expect a carrier to operate even for relatively short periods of time without some resupply of aviation spare parts.

Table 6. Backorder calculations for 30 and 60 days of wartime operations without resupply

	AWP(N)			
	30 days		60 days	
N	LO[a]	HI[b]	LO	HI
0	30	30	500	200
1	10	10	300	90
2	6	6	200	50
3	2	2	100	30
4	0	0	90	20

a. LO: Reconstructed AVCAL with 45-day resupply time.
b. HI: Same as LO AVCAL except items with historical fill rate of 100 percent given infinite stock level.

Using the MAF data, each part number may be assigned to an aircraft-removed/AIMD-removed, repairable/consumable category: an item is categorized as repairable if the MAF data document AIMD inductions for the item and is categorized as a AIMD-removed part if the item is documented as removed from a higher-level part by the AIMD. A breakdown of the part numbers recorded in the MAF data is provided in table 7.

Table 7. Breakdown of MAF data part numbers into part category

Aircraft-removed repairable	Aircraft-removed consumable	AIMD-removed repairable	AIMD-removed consumable
30%	20%	10%	40%
(Total number of distinct part numbers is 19,195)			

Table 8 shows that increasing AIMD-removed part stock levels above that carried in current AVCALs can reduce the number of AWP maintenance actions at the aircraft level, possibly by an order of two; however, increasing *support in* this area will not eliminate the need for off-ship support. In the table, LO+R

corresponds to the LO AVCAL with all AIMD-removed repairable parts given infinite stock levels, and LO+C corresponds to the LO AVCAL with all AIMD-removed consumable parts given infinite stock levels, and so forth. Many aircraft-removed parts are consumable, and others will be declared BCM regardless of the level of AIMD-removed part support; as indicated in table 8, these types of aircraft-removed parts make up a significant portion of the AVCAL effectiveness shortfall.

Table 8. Effect of AIMD-removed parts over 90 days of wartime operations without resupply

	AWP(N)							
N	LO	LO+R	LO+C	LO+R+C	HI	HI+R	HI+C	HI+R+C
0	2,000	2,000	1,000	1,000	500	400	400	300
1	1,000	1,000	800	700	300	200	200	200
2	700	700	500	400	200	100	200	100
3	600	500	400	300	100	100	100	80
4	400	400	300	200	90	70	80	60

LO: Reconstructed AVCAL with 45-day resupply time.
HI: Same as LO AVCAL except items with historical fill rate of 100 percent given infinite stock level.
R: Repairable AIMD-removed parts given infinite stock level.
C: Consumable AIMD-removed parts given infinite stock level.

The appendix contains the results of the backorder calculations by aircraft type as well as by air wing.

TECHNICAL DETAILS

This section contains technical details regarding the methodologies used in the analysis for the reconstructed AVCAL levels and for counting backorders.

DATA QUALITY

The calculation of certain historical maintenance factors was complicated by the poor quality of MAF data; however, MAF data are the only available data from which to address the study topics. (MAFs are the source documents for all Navy aviation maintenance data bases.) A few examples of the major problems from the point of view of this study are discussed here. In general, the analysis was designed to minimize the effect of data-quality problems on the overall outcome of the study results. When it was necessary to introduce bias because of imperfect data, bias was made in the direction of positive AVCAL effectiveness; in other words, the analysis measures of effectiveness tend to indicate the AVCAL is better than it really is.

Many examples in the MAF data indicate that significant numbers of MAFs are "lost" and are never included in the Navy's archive of MAF data. As a result, there is often a serious mismatch between removals and inductions for AIMD-repairable items. Consider the example of a particular type of Inertial Measuring Unit (IMU), a primary navigation device used on the F-14, A-6, S-3, and E-2. This very expensive, highly repairable, mission-essential part has a high failure rate; presumably, some care is taken on the carrier to closely control this item. Theoretically, MAF data will include two distinct entries for each failure of an IMU: a report of the removal of the failed item from an aircraft and a report of the induction of the item into the AIMD for repair. The MAF data from the USS *Constellation* deployment, however, shows 146 documented removals and 210 documented AIMD inductions. The study analysis attempts to reduce the mismatch problem; details will be provided later.

In any real sense, the IMU is an essential item for the mission-effectiveness of its aircraft; however, the maintenance actions associated with IMU removals were sometimes coded as fully-mission-capable (FMC), meaning that removal of the IMU from the aircraft did not affect its ability to perform its mission. For the USS *Constellation* data set, the received equipment-operational-code for IMU removals indicated FMC status for 26 percent of the F-14 IMU removals, 95 percent of the S-3 removals, 33 percent of the E-2 removals, and 63 percent of the A-6 removals. Because of examples like this, the study team decided *not* to distinguish between "FMC" and "downing" maintenance actions.

The MAF documentation procedure for aircraft parts (other than engines) makes it possible to recover indenture structure with reasonable accuracy; unfortunately, aircraft engine repairs are documented differently, in a way that loses much of the indenture structure information available for "ordinary" parts. Loosely, the documentation procedure for engines requires engines to be treated as a "part" when removed from the aircraft, but as an "end item" when in repair. The switch in orientation from part to end item makes tracing parent-child connections for certain engine subparts difficult. The problem is particularly acute for modular engines, as each module is also treated as an end item, making it difficult to retrieve engine-module relationships.

Although indenture information is theoretically recoverable for aircraft engines and modules, it requires the development of non-MAF data bases. Also, given the poor quality of MAF data, the study team concluded that the indenture information would be impossible to recover without considerable guesswork and would be of unknown quality after completion. According to the MAF data, aircraft engines have sufficiently high BCM rates to suggest that the major factor in aircraft engine shortfalls is the engine failure and BCM rate rather than the availability of engine subparts. In addition, aircraft engines are administratively not a part of the official AVCAL: engine allowance levels are set by the type commanders and are functions of aircraft-carrier storage space and the Navy-wide engine procurement situation as well as failure and repair rates. For all these reasons, the study team decided to treat aircraft engines as ordinary aircraft-removed parts in the analysis and not place a special emphasis on analyzing separately the effect of AVCAL shortfalls on aircraft engine availability.

RECONSTRUCTED AVCAL LEVELS

For each part number, two data elements were computed from the historical deployment's MAFs: a day-by-day record of historical supply-room activity and a historical fill rate. Calculations proceed on a part-by-part basis; hence, the discussion assumes that the part number is fixed.

The historical fill rate is computed as follows. Each record of a part demand in the MAF data is accompanied with an indication of the delay between the order and the receipt of the spare part. A stockout was said to occur if three or more days' delay was experienced. The historical fill rate F_h was computed as $F_h = \frac{D-S}{D}$, where S is the total number of stockouts and D is the total number of demands.

The three-day cutoff for in-stock demands was selected for several reasons. First, items in-stock will probably be available in less than three days; hence, the historical fill rate defined above is biased high, possibly resulting in a higher reconstructed AVCAL level. This is consistent with the philosophy of biasing in the direction of better AVCAL quality when a data-processing decision is required. Second, three days is not an unreasonable cutoff, because the on-ship supply response delay for non-mission-essential parts can be one to two days even if the part is in stock.

The following notation is used to describe the historical record of supply-room activity as recovered from MAF data:

- DEMANDS(i) denotes the number of requests for the item on day i of the deployment. (Day 1 corresponds to the first day of the deployment.)
- INDUCTIONS(i) denotes the number of items inducted for repair in the carrier's AIMD on day i.
- REPAIRS(i) denotes the number of items that complete successful repairs at the AIMD on day i.
- BCM(i) denotes the number of items that are declared BCM by the AIMD on day i.

Given the description of historical fill rate, demands, inductions, repairs, and BCMs, the following procedure was used to calculate the fill rate that would have occurred if the off-ship resupply time was R days and the initial stock level was S. The number of items in the repair-resupply pipeline p on day i of the deployment was defined by the following formula. Demands, repairs, and BCMs are denoted d, r, and b, respectively.

$$p(i) = \begin{cases} 0 & \text{if } i = 0 \\ p(i-1) + d(i) - r(i) & \text{if } 1 \leq i < R \\ p(i-1) + d(i) - r(i) - b(i-R) & \text{if } R \leq i \end{cases} .$$

The number of stockouts S_0 that would be experienced with this record of supply room transactions and an initial stock level S is given by the following formula.

$$S_0 = \sum_i \max\{0, p(i) - \max[S, p(i-1)]\} .$$

Hence, the computed fill rate for this part given a stock level S and off-ship resupply time R is

$$F_c(S,R) = 1 - \frac{S_0}{D} \quad ,$$

where $D = \sum_i d(i)$.

The reconstructed AVCAL level, given the off-ship resupply time parameter R, is defined to be the first non-negative integer S that satisfies

$$F_c(S,R) \geq F_h \quad .$$

As was mentioned earlier, there should be a match between demands and inductions for repairable items, but due to data-quality problems, there is often a mismatch. The study team decided that it was important to use a consistent set of data in the reconstructed AVCAL calculation and to avoid using both demands and inductions in a single calculation. If the number of demands was less than twice the number of inductions, it was assumed that the induction-MAF record was relatively complete, and d, r, and b were defined as follows:

$$\begin{aligned} d(i) &= \text{INDUCTIONS}(i) \\ r(i) &= \text{REPAIRS}(i) \\ b(i) &= \text{BCM}(i) \end{aligned} \quad .$$

Otherwise, the item was assumed to be either a consumable or to have an incomplete record of repair activity. In this case d, r, and b were defined as follows:

$$\begin{aligned} d(i) &= \text{DEMANDS}(i) \\ r(i) &= 0 \\ b(i) &= \text{DEMANDS}(i) \end{aligned} \quad .$$

For the purposes of categorizing an item as a repairable or consumable for the analysis reported in tables 7 and 8, the item was declared consumable if the number of demands was more than twice the number of inductions. Otherwise, the part was declared repairable. The item was declared an AIMD-removed part if it was removed at the AIMD at least once. Otherwise, the item was declared an aircraft-removed part.

COUNTING BACKORDERS

Let the collection of distinct part numbers and aircraft types be indexed by i and j. If i is a part of a higher-level item j, then j is called the parent and i is called the child. The notation for certain relationships between a parent-child pair is given in the following paragraphs.

The removal rate of i as a subpart of j is denoted f_{ij}. If j is a repairable aircraft assembly, then

$$f_{ij} = \frac{\text{Total number of demands for } i \text{ originating from } j}{\text{Total number of inductions of } j} \quad .$$

If j is an aircraft, then

$$f_{ij} = \frac{\text{Total number of demands for } i \text{ originating from } j}{\text{Total number of sorties of } j} \quad .$$

The number of potential AWP maintenance actions of a parent item j per demand for a child item i is denoted r_{ij}. If j is a repairable aircraft assembly, then

$$r_{ij} = \frac{\text{Total number of (successful) repairs of } j \text{ requiring } i}{\text{Total number of demands for } i \text{ originating from } j} \quad .$$

For example, if in its application within item j, item i is always requested in units of two when j is successfully repaired, then r_{ij} is $\frac{1}{2}$. This represents the fact that two backorders for item i will stop the repair of only one of item j, assuming cannibalization is possible. If j is an aircraft, then

$$r_{ij} = \frac{\text{Total number of maintenance actions on } j \text{ requiring } i}{\text{Total number of demands for } i \text{ originating from } j} \quad .$$

Two other items computed from the historical data are a BCM rate

$$b_i = \frac{\text{Total number of BCMs of item } i}{\text{Total number of inductions of item } i} \quad ,$$

and an average repair time t_i in days, computed as the average processing *time* over all inductions of i into the AIMD. (For consumable items, $b_i = 1$.)

The variables in the calculations are the initial stock levels s_i, the number of "failure generating events" f_i, and the number of backorders h_i over the wartime period of T days. The variable f_i is defined as follows:

$$f_i = \begin{cases} \text{Number of sorties over period } T & \text{if } i \text{ is an aircraft} \\ \text{Number of demands over period } T & \text{if } i \text{ is a part} \end{cases} .$$

The variables s_i for all i and f_i for all aircraft i are the inputs to the calculation of the number of backorders.

Given as inputs f_i for all aircraft i, the values of f_i for lower-indenture items may be calculated using the following relationship.

$$f_i = \sum f_{ij} f_j \quad \text{(sum over all parents } j\text{)} \ .$$

In practice, the calculation is made recursively, first computing f_i for all aircraft-removed parts, then for the next lowest indenture level, and so forth.

The equation for h_i is rather complicated. Given a child part k has h_k backorders and posting backorders proportionally among parents, parent i has

$$\frac{f_{ki} f_i}{f_k} h_k$$

backorders for item k; these affect

$$r_{ki} \frac{f_{ki} f_i}{f_k} h_k$$

repairs of unit i. The number of backorders h_i for the higher-indenture part i is now made up of several pieces: the number still in processing by the repair pipeline at the end of the time period

$$f_i \frac{t_i}{T}$$

plus the number of items that were not repairable

$$b_i f_i \frac{T - t_i}{T}$$

plus the number of items in AWP status at the end of the time period assuming cannibalization

$$\max\left\{ r_{ki} \frac{f_{ki} f_i}{f_k} h_k : \text{children } k \right\} \frac{T - t_i}{T}$$

less the stock level s_i. Together this leads to the following formula:

$$h_i = \max\left\{ 0, \left[b_i f_i + \max\left(r_{ki} \frac{f_{ki} f_i}{f_k} h_k : \text{children } k \right) \right] \frac{T - t_i}{T} + f_i \frac{t_i}{T} - s_i \right\} \quad .$$

In practice, h_i is first calculated for items at the lowest indenture level. Once these values of h_i are available, the backorders at the next highest indenture level may be calculated, and so on.

Finally, the effect of aircraft-removed part backorders on aircraft maintenance actions is calculated. The number of aircraft i maintenance actions in AWP status because of backorders of aircraft-removed part k is

$$\alpha_{ki} = r_{ki} \frac{f_{ki} f_i}{f_k} h_k \quad .$$

The measure of effectiveness AWP(N) is defined by the following equation:

$$\text{AWP}(N) = \sum \max\{0, \alpha_{ki} - N\} \quad ,$$

where the sum is over all aircraft i and aircraft-removed parts k. The measure of effectiveness P(N) is defined by P(N) = AWP($N - 1$) − AWP(N). When AWP(N) was calculated for the tables in this paper, the α_{ki} were truncated to integers, tending again to underestimate shortfalls in AVCAL effectiveness.

A detailed example, taken from the MAF data used in the analysis, is provided in figure 3. In this example, aircraft-removed part 4 has applications in

aircraft types 1, 2 and 3. The indenture structure of the aircraft-removed part is complicated with several levels of consumable and repairable AIMD-removed parts. In the figure, historical data are unannotated, input numbers are indicated with brackets [ ], and numbers calculated using the formulas for f_i and h_i are indicated with parentheses ( ). First, the values for f_i are computed moving step-by-step down the indenture-structure diagram; next the values of h_i are computed moving step-by-step up the indenture-structure diagram. Finally, using the convention of truncating rather than rounding, aircraft 2 and 3 each have eight AWP maintenance actions associated with aircraft-removed part 4. The corresponding table for AWP(N) may then be calculated. (A wartime period of $T = 90$ days is used in the example.)

As mentioned earlier, for repairable items, there should be a match between demands and inductions, but due to data-quality problems, there is often a mismatch. The following procedure was adapted to partially compensate for missing data when calculating f_{ij}. If

$$0.8(\text{total inductions}) \geq (\text{total demands}) \quad ,$$

then f_{ij} was scaled up by

$$\frac{(\text{total inductions})}{(\text{total demands})} \quad .$$

For example, for the F-14 IMU, the straight calculation of f_{ij} based on documented IMU removals from the F-14 and F-14 sorties is $\frac{72}{1622}$; however, as mentioned earlier, there appears to be a substantial number of missing IMU removal MAFs, with only 146 removals documented in comparison to 210 inductions. To compensate, the f_{ij} used in the analysis for the F-14 IMU was $\frac{72}{1622}\frac{210}{146}$.

No attempt was made to correct misspelled part numbers in the MAF data. If a given part number experienced a lot of activity in the historical data, the reconstructed AVCAL level and the computed backorders at the end of the wartime period should be substantially correct. The loss of any of the historical activity because the part number was misspelled on some MAFs will result in both reduced reconstructed AVCAL levels and reduced demands during the wartime backorders calculations. The resulting errors should be biased in the direction of fewer backorders, that is, toward estimating the AVCAL as better than it *really* is. Misspelled part numbers should receive little historical activity and will tend

Indenture structure:

1		2		3	Aircraft
	↘	↓	↙		
		4			Level 1 (Aircraft-removed parts)
	↙	↓	↘		
5		6		7	Level 2 (AIMD-removed parts)
	↙	↓	↘		
8		9		10	Level 3 (AIMD-removed parts)
	↙	↓	↘		
11		12		13	Level 4 (AIMD-removed parts)

Maintenance factors:

Child i	Parent j	f_{ij}	r_{ij}
4	1	0.003003	1.0000
4	2	0.027002	1.0000
4	3	0.011097	1.0000
5	4	0.020408	1.0000
6	4	0.714285	0.9142
7	4	0.061224	0.3333
8	6	0.657142	0.6923
9	6	0.114285	0.7500
10	6	0.714285	0.6111
11	9	0.250000	1.0000
12	9	0.250000	1.0000
13	9	0.750000	0.6666

Figure 3. Counting backorders—example 2

Calculation of demands and effects of lower-level parts:

i	s_i	b_i	t_i	f_i	h_i
1	[0]	0.0000	0.0	[360]	(0.382)
2	[0]	0.0000	0.0	[900]	(8.952)
3	[0]	0.0000	0.0	[2160]	(8.825)
4	[7]	0.0000	16.2	(49.3539)	(18.196)
5	[0]	1.0000	0.0	(1.0072)	(1.007)
6	[1]	0.0769	26.7	(35.2527)	(21.758)
7	[0]	1.0000	0.0	(3.0216)	(3.021)
8	[4]	1.0000	0.0	(23.1661)	(19.166)
9	[0]	0.0000	19.5	(4.0248)	(2.450)
10	[1]	1.0000	0.0	(25.1805)	(24.180)
11	[0]	1.0000	0.0	(1.0072)	(1.007)
12	[0]	1.0000	0.0	(1.0072)	(1.007)
13	[0]	1.0000	0.0	(3.0216)	(3.021)

Calculation of AWP(N) and P(N):

N	AWP(N)	P(N)
0	(16)	(2)
	(14)	(2)
2	(12)	(2)
3	(10)	(2)
4	(8)	(2)

Figure 3. (Continued)

to have small reconstructed AVCAL levels and few wartime demands. The computed number of wartime backorders charged against misspelled part numbers will be small and should have little effect on AWP(N), at least for $N = 3, 4$.

APPENDIX

RESULTS BY AIRCRAFT TYPE AND AIR WING

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RESULTS BY AIRCRAFT TYPE AND AIR WING

This appendix contains the results of the backorder calculations by aircraft type, as well as by air wing. The results have not been rounded, but they should not be considered more accurate than one significant digit.

LO: Reconstructed AVCAL with 45-day resupply time, backorder calculations for 90 days of wartime operations without resupply

	AWP(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	1,854	74	74	166	36	967	14	155	368
1	1,058	30	31	105	21	568	4	90	209
2	741	17	21	80	13	403	0	65	142
3	554	11	18	65	7	291	0	56	106
4	433	8	17	53	4	219	0	53	79

	P(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	796	44	43	61	15	399	10	65	159
1	317	13	10	25	8	165	4	25	67
2	187	6	3	15	6	112	0	9	36
3	121	3	1	12	3	72	0	3	27

HI: Same as LO AVCAL except items with historical fill rate of 100 percent given infinite stock level, backorder calculations for 90 days of wartime operations without resupply

	AWP(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	460	12	23	56	5	210	2	39	113
1	262	4	7	34	1	137	1	14	64
2	178	1	2	23	0	104	0	3	45
3	127	0	0	15	0	78	0	0	34
4	92	0	0	8	0	59	0	0	25

	P(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	198	8	16	22	4	73	1	25	49
1	84	3	5	11	1	33	1	11	19
2	51	1	2	8	0	26	0	3	11
3	35	0	0	7	0	19	0	0	9

LO-30: LO AVCAL, backorder calculations for 30 days of wartime operations without resupply

	AWP(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	31	0	0	6	0	17	0	0	8
1	14	0	0	2	0	8	0	0	4
2	6	0	0	1	0	3	0	0	2
3	2	0	0	0	0	1	0	0	1
4	0	0	0	0	0	0	0	0	0
	P(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	17	0	0	4	0	9	0	0	4
1	8	0	0	1	0	5	0	0	2
2	4	0	0	1	0	2	0	0	1
3	2	0	0	0	0	1	0	0	1

HI-30: HI AVCAL, backorder calculations for 30 days of wartime operations without resupply

	AWP(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	30	0	0	6	0	17	0	0	7
1	14	0	0	2	0	8	0	0	4
2	6	0	0	1	0	3	0	0	2
3	2	0	0	0	0	1	0	0	1
4	0	0	0	0	0	0	0	0	0
	P(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	16	0	0	4	0	9	0	0	3
1	8	0	0	1	0	5	0	0	2
2	4	0	0	1	0	2	0	0	1
3	2	0	0	0	0	1	0	0	1

LO-60: LO AVCAL, backorder calculations for 60 days of wartime operations without resupply

	AWP(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	505	5	15	49	7	283	1	43	102
1	258	0	8	28	1	147	0	23	51
2	162	0	7	21	0	86	0	20	28
3	114	0	6	17	0	59	0	18	14
4	87	0	5	15	0	43	0	16	8
	P(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	247	5	7	21	6	136	1	20	51
1	96	0	1	7	1	61	0	3	23
2	48	0	1	4	0	27	0	2	14
3	27	0	1	2	0	16	0	2	6

HI-60: HI AVCAL, backorder calculations for 60 days of wartime operations without resupply

	AWP(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	174	3	5	26	3	85	0	12	40
1	86	0	0	12	0	53	0	0	21
2	52	0	0	6	0	35	0	0	11
3	32	0	0	3	0	25	0	0	4
4	22	0	0	2	0	18	0	0	2
	P(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	88	3	5	14	3	32	0	12	19
1	34	0	0	6	0	18	0	0	10
2	20	0	0	3	0	10	0	0	7
3	10	0	0	1	0	7	0	0	2

LO+R: Same as LO AVCAL, except repairable AIMD-removed parts given infinite stock level, backorder calculations for 90 days of wartime operations without resupply

	AWP(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	1,714	70	73	144	33	907	13	140	334
1	967	28	31	88	20	523	3	84	190
2	682	17	21	67	13	369	0	62	133
3	512	11	18	56	7	266	0	56	98
4	402	8	17	48	4	200	0	53	72

	P(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	747	42	42	56	13	384	10	56	144
1	285	11	10	21	7	154	3	22	57
2	170	6	3	11	6	103	0	6	35
3	110	3	1	8	3	66	0	3	26

HI+R: Same as HI AVCAL, except repairable AIMD-removed parts given infinite stock level, backorder calculations for 90 days of wartime operations without resupply

	AWP(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	402	11	23	38	3	192	2	31	102
1	217	3	7	19	0	122	1	10	55
2	143	1	2	11	0	91	0	1	37
3	100	0	0	6	0	68	0	0	26
4	73	0	0	3	0	52	0	0	18

	P(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	185	8	16	19	3	70	1	21	47
1	74	2	5	8	0	31	1	9	18
2	43	1	2	5	0	23	0	1	11
3	27	0	0	3	0	16	0	0	8

LO+C: Same as LO AVCAL, except consumable AIMD-removed parts given infinite stock level, backorder calculations for 90 days of wartime operations without resupply

	AWP(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	1,473	63	68	139	32	781	13	72	305
1	783	25	29	92	19	432	4	26	156
2	518	15	20	71	12	293	0	5	102
3	369	10	18	58	7	203	0	0	73
4	271	8	17	49	4	143	0	0	50

	P(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	690	38	39	47	13	349	9	46	149
1	265	10	9	21	7	139	4	21	54
2	149	5	2	13	5	90	0	5	29
3	98	2	1	9	3	60	0	0	23

HI+C: Same as HI AVCAL, except consumable AIMD-removed parts given infinite stock level, backorder calculations for 90 days of wartime operations without resupply

	AWP(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	393	11	20	46	4	181	2	31	98
1	221	3	5	28	1	118	1	13	52
2	150	1	1	19	0	88	0	2	39
3	108	0	0	12	0	66	0	0	30
4	78	0	0	7	0	50	0	0	21

	P(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	172	8	15	18	3	63	1	18	46
1	71	2	4	9	1	30	1	11	13
2	42	1	1	7	0	22	0	2	9
3	30	0	0	5	0	16	0	0	9

LO+R+C: Same as LO AVCAL, except all AIMD-removed parts given infinite stock level, backorder calculations for 90 days of wartime operations without resupply

	AWP(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	1,289	59	67	111	29	700	12	61	250
1	667	23	29	73	18	377	3	21	123
2	446	15	20	58	12	252	0	3	86
3	318	10	18	50	7	172	0	0	61
4	237	8	17	45	4	121	0	0	42
	P(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	622	36	38	38	11	323	9	40	127
1	221	8	9	15	6	125	3	18	37
2	128	5	2	8	5	80	0	3	25
3	81	2	1	5	3	51	0	0	19

HI+R+C: Same as HI AVCAL, except all AIMD-removed parts given infinite stock level, backorder calculations for 90 days of wartime operations without resupply

	AWP(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	312	9	20	24	2	154	2	25	76
1	162	2	5	12	0	95	1	10	37
2	107	1	1	7	0	69	0	1	28
3	75	0	0	4	0	51	0	0	20
4	57	0	0	3	0	40	0	0	14
	P(N)								
N	CVW	EA6	KA6	A6	E2	F14	SH6	F18	S3
0	150	7	15	12	2	59	1	15	39
1	55	1	4	5	0	26	1	9	9
2	32	1	1	3	0	18	0	1	8
3	18	0	0	1	0	11	0	0	6